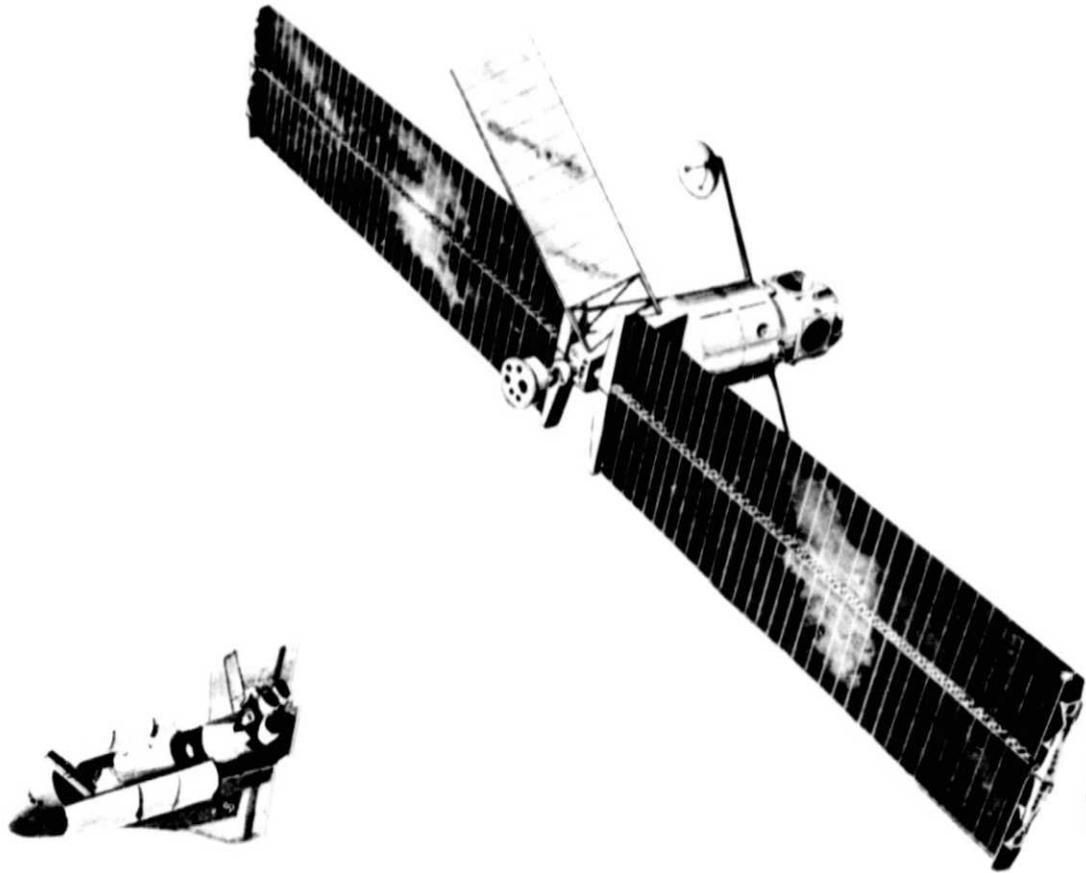


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**NASA**

George C. Marshall  
Space Flight Center

# 25 kW POWER MODULE EVOLUTION STUDY

**VOLUME 6 WBS AND DICTIONARY  
PART III : CONCEPTUAL DESIGNS FOR POWER MODULE EVOLUTION  
FINAL REPORT**

LOCKHEED MISSILES & SPACE COMPANY, INC.

FINAL REPORT

25kW POWER MODULE EVOLUTION STUDY

PART III: CONCEPTUAL DESIGN FOR POWER MODULE EVOLUTION

VOLUME 6: WBS & DICTIONARY

27 JANUARY, 1979

SUBMITTED TO THE  
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION  
Marshall Space Flight Center  
Huntsville, Alabama 35812

Contract NAS8-32928

DPD 555

MA-06

LOCKHEED MISSILE & SPACE COMPANY, INC  
SUNNYVALE, CALIFORNIA

## FOREWORD

This volume of the Part III Final Report for the 25 kW Power Module Evolution Study was prepared by Lockheed Missiles and Space Company, Inc. for the George C. Marshall Space Flight Center (MSFC), National Aeronautics and Space Administration (NASA), under Contract No. NAS8-32928.

The objective of the study was to define how the 25 kW Power Module can be evolved by the addition of system elements in evolutionary steps to meet the future mission requirements. For each step, conceptual designs were prepared. The level of capability at each step was commensurate with the mission and payload requirements. Emphasis was placed on the near-term steps beyond the 25 kW PM.

The study activity comprised the following parts/tasks:

- o Part I - Payload Requirements and Growth Scenarios (LMSC, TRW, and Bendix)

This analytical effort was conducted to develop payload application summaries and time-phased requirements that will drive the concepts for the 25 kW Power Module and the supporting systems definitions (for the period 1983-1990). The Part I effort was documented in Final Report LMSC-D614921A, dated 1 August 1978.

- o Part II - Payload Support System Evolution (LMSC, IBM, and Bendix)

This effort was devoted to establishing baseline program support elements and candidate evolutionary growth capabilities for final candidate definition (element data, cost, mods, development sequence, and precursor missions). The Part II effort was documented in Final Report LMSC-D614928A, dated 30 September 1978.

## FOREWORD (Continued)

- o Part III - Conceptual Designs for Power Module Evolution (LMSC, Bendix)

This effort was conducted to establish design approaches for the evolutionary systems, to develop associated programmatic data, and to assess the evolution scenario and capabilities of the 25 kW Power Module for representative missions.

This report constitutes Volume 6, WBS & Dictionary, of the Part III Final Report. It meets the requirements of Contract No. NAS8-32928 Data Procurement Document, Data Requirement MA-06 Final Study Report.

The volumes comprising the Part III Final Report are:

- o Volume 1 - PM Evolution
- o Volume 2 - Program Plans
- o Volume 3 - Cost Estimates
- o Volume 4 - Design Analyses
- o Volume 5 - Mission Accommodations
- o Volume 6 - WBS and Dictionary

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WBS ELEMENT DICTIONARY  
FOR THE  
POWER MODULE SYSTEM

## 1.0 INTRODUCTION

This dictionary identifies, structures and defines program elements of the Power Module (PM) System, according to the planned PM Work Breakdown Structure (WBS). That structure is graphically presented in Figure 1.

## 2.0 POWER MODULE PROJECT DESIGN REFERENCE

The PM Project Design Reference used for preparation of the WBS and this WBS dictionary is defined by the several volumes of the 25 kW Power Module Evolution Study Final Report.

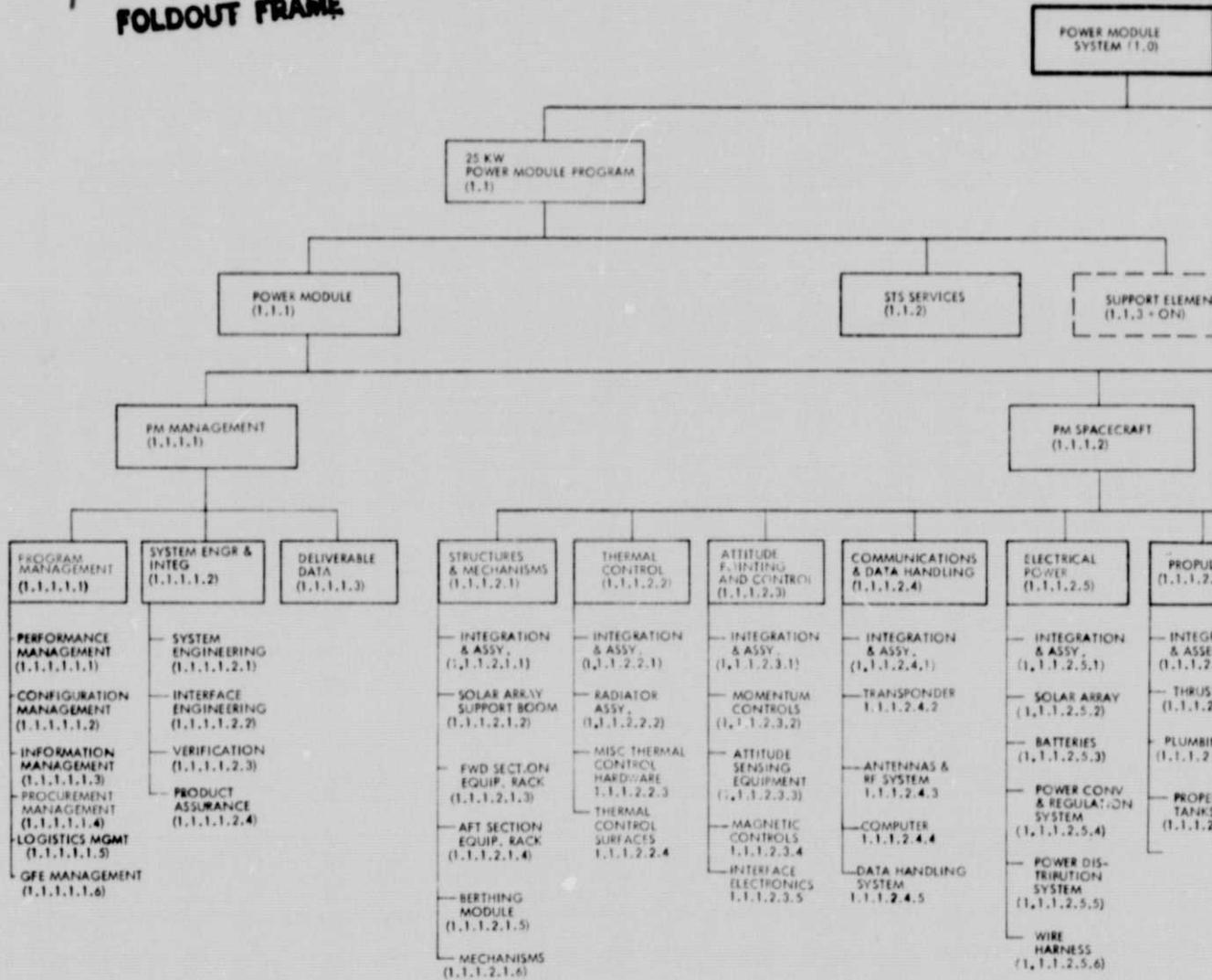
## 3.0 SCOPE

This WBS encompasses the effort required to design, develop, manufacture, test, checkout, launch and operate a protoflight assembled 25 kW, 50 kW and 100 kW PM. This includes the preparation and delivery of related software, Government Furnished Equipment (GFE), Space Support Equipment (SSE), Ground Support Equipment (GSE), launch site verification software, orbital verification software, and all related data items.

## 4.0 SCHEDULE

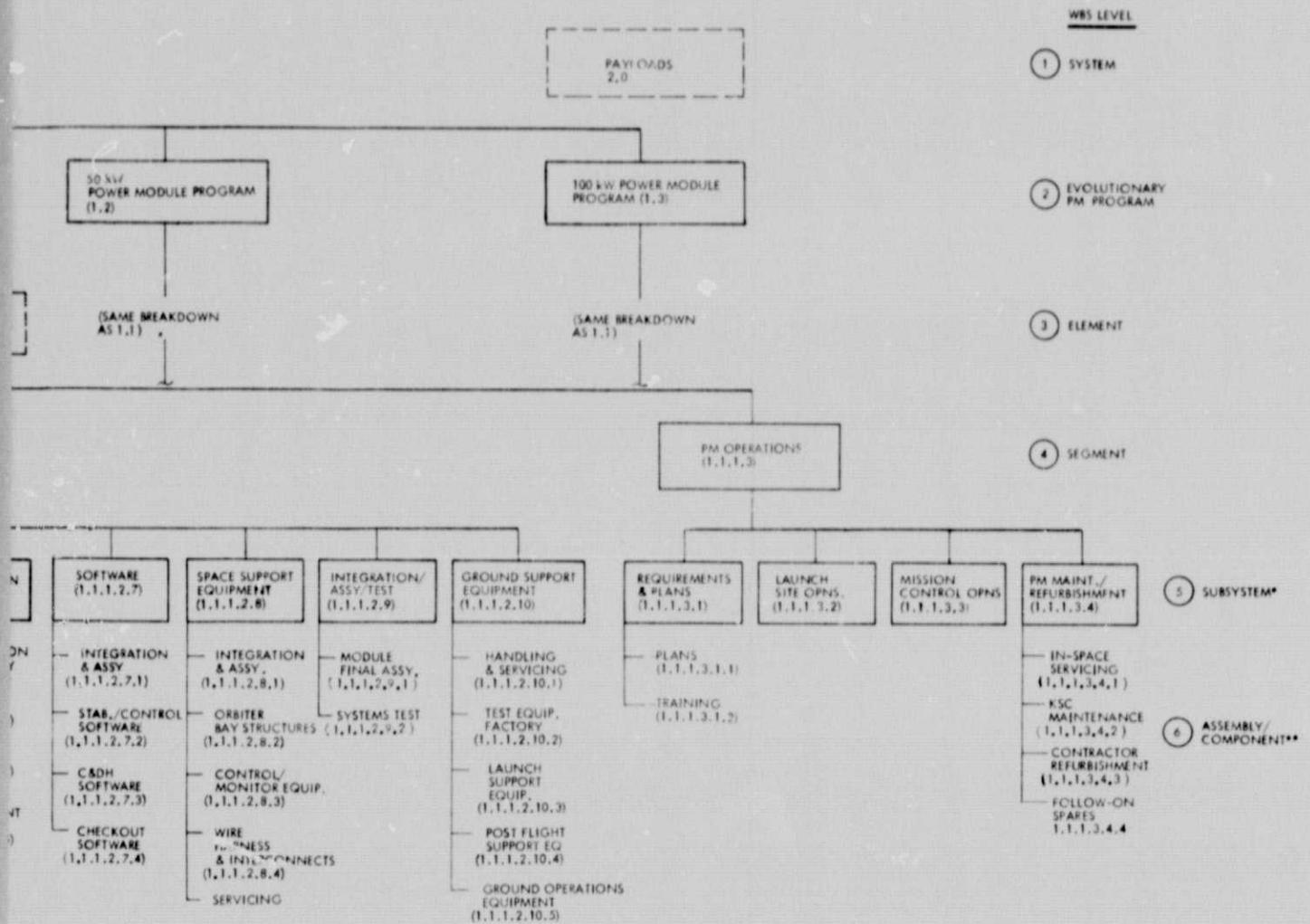
The implementation schedule for program efforts and delivery schedule for the program end item are provided in the Program Plan, Volume 2, of this Report.

# FOLDOUT FRAME



\* LEVEL 5 IS KEY COST-REPORTING LEVEL; VISIBILITY INTO ENGINEERING, TEST-HARDWARE, PRODUCTION (AND FIRST-UNIT), AND SPARES COSTS

\*\* LEVEL 6 BACKUP DATA INCLUDE ENGINEERING, PRODUCTION AND TOOLING COSTS DOWN TO COMPONENT LEVEL



2  
FOLDOUT FRAME

Figure 1. Work Breakdown Structure

## 5.0 DEFINITION OF PROGRAM ELEMENTS

### 1.0 Power Module System

The PM System is comprised of a number of PM Programs which collectively provide on-orbit operational support capabilities for various payloads and combinations of payloads, in various orbits and in either free-flyer and/or sortie modes. Presently, identified operational support levels for electrical power call for a 25 kW PM, a 50 kW PM, and a 100 kW PM. Operational support to be provided to the several payloads and combinations of payloads includes not only the electrical power requirements, but also the thermal control/heat rejection requirements, coincident to the power levels provided, attitude pointing and control, communications data handling, and the PM portion of a berthing interface with payloads and/or Space Transportation System (STS) delivery vehicles.

#### 1.1.0 25 kW POWER MODULE PROGRAM

This is a Level 2 summing element for a complete 25 kW PM Program, which is the initial step of an evolutionary space PM system. It encompasses all efforts of the program to engineer, manufacture, test, deploy, operate, maintain, and retrieve 25 kW PMs communications, to provide electrical energy and associated services, including on-orbit power, attitude control and thermal heat rejection to (1) the orbiting Shuttle system (i.e., Orbiter, Spacelab and other docked payloads), and (2) free-flying payloads.

#### 1.1.1 POWER MODULE

This is a Level 3 summing element for a complete 25 kW PM. It encompasses all effort described under WBS elements 1.1.1.1 (PM Management), 1.1.1.2 (PM Spacecraft) and 1.1.1.3 (PM Operations), to perform the following: (1) establish detailed requirements, (2) design and develop a PM in compliance with technical requirements specified in the system specification and conduct the necessary analyses and studies to proof the design, (3) establish and maintain interface control, (4) prepare and maintain plans for the accomplishment of production, (5) produce, qualify and test PM hardware and associated software,

assemble and integrate to produce a PM, and test and deliver completed PMs, (6) produce, test and deliver required support equipment to support test, launch and mission operations, (7) plan for and support PM maintenance and refurbishment activities, and conduct launch preparation, launch, deployment, on-orbit operation and retrieve 25 kW PMs.

#### 1.1.1.1 SYSTEM/PROJECT MANAGEMENT

This is a Level 4 summing element for the 25 kW PM Program Management and System Engineering effort, and includes the effort to provide deliverable data. It encompasses all effort described under WBS elements 1.1.1.1.1 (Program Management), 1.1.1.1.2 (System Engineering & Integration), and 1.1.1.1.3 (Deliverable Data).

##### 1.1.1.1.1 PROGRAM MANAGEMENT

This Level 5 summing element covers the program management effort required to (1) plan, schedule, organize, control, administer and report on overall PM Project activities; (2) ensure control and accountability of PM system and interface configurations; (3) ensure timely availability and transfer of information to support the on-going PM project effort; (4) ensure timely development, production and support of subcontracted or purchased PM hardware; (5) support NASA planning and preparation for a PM logistics support function, and provide PM logistics management through initial PM launch operation; and (6) plan, schedule, coordinate, monitor and report on PM GFE.

##### 1.1.1.1.2 SYSTEM ENGINEERING AND INTEGRATION

This level 5 summing element covers the system engineering planning; requirements assessment, allocation and verification; definition of system interfaces and the planning and control of those interfaces; system verification/validation plans, tests, analyses and certification of compatibility/suitability of the Power Module with all external interfaces; and system effectiveness functions in the forms of safety engineering, reliability analyses, maintainability, and quality engineering. Quality Assurance inspections and testing of

PM hardware, SSE, GSE, Spares and PM integration, assembly and test are specifically excluded. (These exclusions are covered under WBS Element 1.1.1.2, PM Spacecraft.)

#### 1.1.1.1.3 DELIVERABLE DATA

This is a Level 5 summing element for deliverable data included on Data Procurement Documents (DPDs). Data input is produced by other WBS elements. This element covers functions associated with coordination, publication, packaging and transmittal in accordance with DPD requirements. The effort required under this WBS element provides for the specific documentation work necessary to satisfy customer content and format requirements and the development, preparation, publication and reproduction of those data requirements.

#### 1.1.1.2 PM SPACECRAFT

This is a Level 4 summing element for the design, development, fabrication, assembly, integration and test of the 25 kW Power Module spacecraft, including (1) design, development and verification (qualification) of spacecraft hardware and software and SSE, and subsequent fabrication, subassembly and acceptance tests of spacecraft and SSE flight units, (2) design, fabrication and proof test of PM Project GSE, (3) integration, assembly and system test of the PM spacecraft, and (4) fabrication and proof test of subsystem special tooling and test equipment. It sums all effort described under the following WBS elements:

- 1.1.1.2.1 Structures and Mechanisms Subsystem
- 1.1.1.2.2 Thermal Control Subsystem
- 1.1.1.2.3 Attitude Pointing & Control Subsystem
- 1.1.1.2.4 Communications & Data Handling
- 1.1.1.2.5 Electric Power Subsystem
- 1.1.1.2.6 Propulsion Subsystem
- 1.1.1.2.7 Software Subsystem
- 1.1.1.2.8 Space Support Equipment
- 1.1.1.2.9 Integration, Assembly & Test
- 1.1.1.2.10 Ground Support Equipment

#### 1.1.1.2.1 STRUCTURES AND MECHANISMS SUBSYSTEM (SMS)

This is a Level 5 summing element for design, development and production of all structures, mechanisms, and PM structural interfaces with Shuttle Orbiter and the free-flying payloads. Structures include the equipment section(s), structural support interface hardware, solar array support structure and docking structure. Mechanisms include deployment assemblies (booms, extension/retraction assemblies, gimbal assemblies, and associated support structure), latch mechanisms, and mechanism control units for the solar arrays, radiators, and other deployable devices. SMS initial spares are included in this element.

#### 1.1.1.2.2 THERMAL CONTROL SUBSYSTEM (TCS)

This is a Level 5 summing element for design, development and production of all active and passive thermal control equipment including radiator panels, fluid loops, heat exchangers, cold plates for equipment mounting, and other thermal control equipment necessary to maintain temperatures within allowable limits. Radiator mechanisms are excluded as they are under WBS 1.1.1.2.1 (SMS). TCS initial spares are included in this element.

#### 1.1.1.2.3 ATTITUDE POINTING & CONTROL SUBSYSTEM (APCS)

This is a Level 5 summing element for design, development and production of PM spacecraft stabilization and control hardware, which includes attitude sensing equipment, momentum control equipment (CMGs), computer(s), memory load unit, and a work shop computer interface unit. APCS initial spares are included in this element.

#### 1.1.1.2.4 COMMUNICATIONS & DATA HANDLING SUBSYSTEM (C&DHS)

This is a Level 5 summing element for design, development and production of equipment, which will comprise (1) a communications system to receive and modulate commands, provide coherent ranging, and transmit engineering and science data, (2) a data management system to acquire, process, store and disseminate all information between the PM and the mission control center, and

(3) unincorporated instrumentation for temperature and contamination monitoring. C&DHS initial spares are included in this element.

#### 1.1.1.2.5 ELECTRICAL POWER SUBSYSTEM (EPS)

This is a Level 5 summing element for design, development and production of electrical power equipment, which includes the solar array, batteries, power distribution and control system and interconnect cables. Mechanisms for the solar array are excluded; they are under WBS 1.1.1.2.1. EPS initial spares are included in this element.

#### 1.1.1.2.6 PROPULSION SUBSYSTEM (PS) (To be defined)

#### 1.1.1.2.7 SOFTWARE SUBSYSTEM (SWS)

This is a Level 5 summing element for development of flight software which consists of on-board software which executes in the data management subsystem D&DH module for status analysis, telemetry format control, antenna, solar array and radiator panel control command processing, and self-test diagnosis. This element covers (1) flight software coding, (2) development, (3) checkout of flight software during PM system verification, and (4) modification of vendor supplied and other general purpose software to support design and development of the flight software.

#### 1.1.1.2.8 SPACE SUPPORT EQUIPMENT (SSE)

This is a Level 5 summing element for design, development and production of SSE. This equipment consists of a complete set of portable PM-peculiar mechanical and electrical equipment which is installed onboard the Orbiter. PM functions supported by this Orbiter installed equipment include on-orbit PM extra-vehicular activities, PM deployment, berthing, and/or maintenance. SSE spares are included in this element.

#### 1.1.1.2.9 INTEGRATION/ASSEMBLY/TEST

This is a Level 5 summing element for the final integration and assembly of the PM and to conduct systems test and verification. It covers the effort

required to plan and perform the PM assembly, checkout, data analysis, evaluation and demonstrations which verify PM compatibility, capability and readiness to perform in compliance with its design requirements.

#### 1.1.1.2.10 GROUND SUPPORT EQUIPMENT (GSE)

This is a Level 5 summing element for design, development and production of GSE, which is a functional assemblage of nonflight hardware scheduled for delivery to the customer for support of the PM. It includes assembly, handling and test equipment required to inspect, test, adjust, calibrate, assemble, disassemble, service, handle, transport, or simulate all or part of the PM. GSE spares are included in this element.

#### 1.1.1.3 OPERATIONS

This is a Level 4 summing element for the planning of and conducting contractor tasks or supporting customer tasks in the preparation for launch, launch, orbit insertion and verification, mission operations, and maintenance/ refurbishment of the PM spacecraft.

##### 1.1.1.3.1 REQUIREMENTS AND PLANS

This is a Level 5 summing element for operations analyses, requirements determination and planning for fulfillment of those requirements in the specific areas of (1) Launch & Crew Operations; (2) Mission Control Operations; (3) Maintenance/Refurbishment; (4) Operations Training; and (5) Training Aids.

##### 1.1.1.3.2 LAUNCH SITE OPERATIONS

This is a Level 5 summing element for PM contractor effort in support of PM launch operations, to prepare for and accomplish the tasks required to receive and prepare PM hardware at the launch site, support pre-launch and launch operations, and return SSE and GSE to the factory following launch and Orbiter return to earth. This includes verification of the accomplishment of tasks mentioned above and to maintain verification records.

#### 1.1.1.3.3 MISSION CONTROL OPERATIONS

This is a Level 5 summing element for PM contractor effort in support of mission operations. Mission operations start immediately following orbital verification. Such operations will be conducted from the Mission Control Center (MCC) at NASA-JSC and include execution of procedures, tests, calibrations and functions required to operate and maintain the performance of the PM and associated ground facilities. The effort includes preparation for mission operations on-site at JSC, simulation software for MCC, integration and checkout of that software at the MCC, and simulation exercises for verification and training purposes.

#### 1.1.1.3.4 PM MAINTENANCE/REFURBISHMENT

This is a Level 5 summing element for the PM contractor's effort to develop plans and procedures for inflight contingency maintenance, planned in-space servicing operations, ground maintenance activities and PM refurbishment.

#### 1.2 50 kW Power Module Program

The program elements identified and defined in the preceding pages for the 25 kW PM Program are generally applicable to the 50 kW PM Program. For clarification and essential segregation purposes, however, the elements for the 50 kW PM require the initial two-digit number designator of 1.2 instead of the 1.1 designator used as a prefix for the 25 kW PM Program elements.

#### 1.3 100 kW Power Module Program

The program elements identified and defined in the preceding pages for the 25 kW PM Program are generally applicable to the 100 kW PM Program. For clarification and essential segregation purposes, however, the elements for the 100 kW PM Program require the initial two-digit number designator of 1.3 instead of the 1.1 designator used as a prefix for the 25 kW Power Module Program elements.